NAVAL POSTGRADUATE SCHOOL
Monterey, California

EC 3550 FINAL EXAM 12/90Po

- This exam is open book and notes.
- There are four problems; each is equally weighted.
- Partial credit will be given; be sure to do some work on each problem.
- Be sure to include units in your answers.
- Please circle or underline your answers.
- Show *ALL* work.

1	
2	
3	
4	
Total	

Name: ____________________

Note: Data about fibers and devices are found in the attached tables.

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1. Fiber #2 is operated at 820 nm.
   (a) Calculate $\theta_{\max}$ (*in degrees*) for this fiber.
   (b) Calculate the fraction (*in percent*) of the total power that is carried in the core of the fiber.

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2. Laser #4 is used in a fiber link that uses fiber #3. The link distance is 8.7 km and has eight splices. The splice loss is 0.3 dB when joining fibers with the same properties.
   (a) Calculate the coupling loss at the laser–pigtail/fiber joint if the total of all of the misalignment losses are known to be 0.8 dB.
   (b) Calculate the link's margin if the power required at the receiver is 0 dBμ. (You may assume that the coupling losses from the fiber to the detector are 0 dB.)

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3. Fiber #2 is to be used with LED #3 in a 30 Mb/s link. Fiber #2 has an index of refraction of the core of 1.46. The power required at the receiver (in dBm) is given by

$$P_R(\text{dBm}) = (8.7\log(\text{DR})) - 71.0 \tag{1}$$

   where DR is in Mb/s. The coding is NRZ.
   (a) Calculate the attenuation–limited link distance if both the coupling losses and the joint losses are ignored and the aging allowance is 0 dB.
   (b) Calculate the dispersion–limited transmission distance for material dispersion.
   (c) Calculate the dispersion–limited transmission distance for modal dispersion.

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4. Detector #1 is operated at 820 nm with a gain of 150. The signal bandwidth is 5 MHz.
   (a) Calculate the noise–equivalent power (NEP) of this detector assuming that the signal–dependent shot noise is dominant.
   (b) Using the result of the previous part, calculate the value of R_L required to make the thermal noise equal to 1/100 of the signal–dependent shot noise when the NEP is incident on the detector. (The noise temperature of the detector is 390K.)

FIBER SPECIFICATIONS

	Fiber #1	Fiber #2	Fiber #3	Fiber #4
Size	50/125	62.5/125	8/125	100/140
g	1.90	∞	∞	1.78
NA	0.15 (at $r=0$)	0.20	0.10	0.18 (at $r=0$)
α @ 820 nm	3.0 dB/km	2.0 dB/km	0.9 dB/km	5.0 dB/km
α @ 1300 nm	1.0 dB/km	1.20 dB/km	0.5 dB/km	2.0 dB/km
α @ 1550 nm	0.8 dB/km	0.7 dB/km	0.4 dB/km	0.6 dB/km

SOURCE SPECIFICATIONS

	Laser #1	Laser #2	LED #3	Laser #4
Wavelength	820 nm	1300 nm	820 nm	1550 nm
$\Delta\lambda$	2.0 nm	4.0 nm	10 nm	30 nm
Power at pigtail end	0.50 mW	0.8 mW	5 μW	3.0 dBm
Pigtail size	200/300 μm	10/125 μm	200/300 μm	10/125 μm
Pigtail NA	0.25	0.12	0.25	0.12
Pigtail type	Step index	Step index	Step index	Step index

DETECTOR SPECIFICATIONS

	Detector #1	Detector #2	Detector #3
Material	Silicon	Germanium	InGaAs
Responsivity A/W @ $M=1$	0.8 @ 820 nm	0.2 @ 1300 nm 0.45 @ 1550 nm	0.2 @ 1300 nm 0.3 @ 1550 nm
C_d	3 pF	1 pF	2 pF
Excess noise factor	$M^{0.3}$	M^{1}	$M^{0.6}$
Bulk dark current	0.10 pA	10 μA	0.1 μA
Surface dark current	0	0	0